9. Acid Mine Drainage Prediction

ACID MINE DRAINAGE: COMPARISON OF LABORATORY TESTING TO MINE SITE CONDITIONS
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Fourth International Conference on Acid Rock Drainage, 31 May-6 June 1997, Vancouver, Canada
CANMET, Natural Resources Canada, Ottawa, ON (Canada). Vol 1, p 305-318, 1997

Four coal mine coarse waste heaps were built above ground to study the acid mine drainage potential of mineral wastes. The objective is to assess the performance of static and kinetic laboratory-based tests for predicting potential and actual acid producing potential and acid production under field conditions. The reject material contains 0.22 % total sulphur. Testing is over a two-year period. Monitoring, sampling, and test methods for assessing the acid generating potential of the waste are described. The results obtained from the laboratory based tests and acid production measured in field tests are compared.

A CONCEPTUAL ROCK CLASSIFICATION SYSTEM FOR WASTE MANAGEMENT AND A LABORATORY METHOD FOR ARD PREDICTION FROM ROCK PILES
Brodie, M.J.; L.M. Broughton; A.M. Robertson
Steffen, Robertson and Kirsten (B.C.) Inc, Vancouver, BC (Canada)
Proceedings. Second International Conference on the Abatement of Acidic Drainage, 16-18 Sep 1991, Montreal (Canada)
MEND Program, Ottawa, Ontario, Canada. Check or money order for $150.00 to Quebec Mining Association, for 4 vols. ISBN: 2-551-12727-0. ER--91-5064, p 119-135 (paper 3.5), 1991

The purpose is to present two methods to improve prediction of potential acid rock drainage and drainage water quality. One method is a rock classification system that characterizes the geochemical and physical properties of a rock unit with reference to acid rock drainage. This classification supplements static and kinetic prediction methods to assist decision making with regards to rock disposal and requirements for acid rock drainage control during mining. The second method is a modified large scale humidity cell to simulate the conditions in a rock pile.

SULFIDE AND CARBONATE AVAILABILITY AND GEOCHEMICAL CONTROLS ESTABLISHED FROM LONG-TERM COLUMN TESTS
Chapman, J. (SRK Consulting, Brisbane, Australia): M. Paul; S. Jahn (WISMUT, Chemnitz, Germany); D. Hockley (SRK Consulting, Vancouver, BC)
Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 581-590, ©2000

As part of the waste characterization program to address site reclamation, WISMUT GmbH initiated 56 columns operated as large-scale humidity cell tests. The columns were initiated to assess the acid generation characteristics of waste rock from 14 waste rock piles distributed around the site. Of the 56 tests, 11 are ongoing and have been operational in excess of 160 weeks. The results to date from these long-term tests are summarized. In particular, the methods for, and importance of, establishing the

availability of the carbonate neutralization potential and acid generation potential respectively, are discussed. Geochemical controls on uranium, and the conformity between the geochemical models MINTEQA2 and EQ3/6 in assessing these controls are discussed. Testing indicates that waste rock with an MS-NP:AP ratio in excess of about 2.7 should result in net neutral pH conditions.

LITHOGEOCHEMICAL METHODS FOR ACID ROCK DRAINAGE STUDIES AND PREDICTION
Downing, B.W.; H.E. Madeisky
Exploration and Mining Geology, Vol 6 No 4, p 367- , 01 Oct 1997

ASSESSING THE RISK OF ARD
Ferguson, K.D.; J.D. Robertson
Placer Dome Canada, Ltd., Vancouver, British Columbia (Canada)
Proceedings of the International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage, 24-30 Apr 1994, Pittsburgh, PA
Report No: BUMINES-SP-06D-94. NTIS: PB96-113519NEG. Vol 4, p 2-11, 1994

Predictions of the potential for acid rock drainage (ARD) usually focus on assessing the probability that samples and waste units will generate contaminated leachate. The rate of ARD generation, its quantity, and the possible consequences of release are usually considered in far less detail. Such analyses are deficient and do not fully assess the risk of ARD. Risk can be quantified as the product of probability of an event occurring times consequences. The result is modified by the mitigative measures or contingency plans proposed to prevent or control the undesirable event. Several methods of risk assessment are available and might be applicable to assessing the risk of ARD. These include, qualitative assessments, what if analysis, point-scoring systems, failure mode and effect analysis (FMEA), and quantitative probabilistic analysis. The first three simple approaches are more appropriate for advanced exploration and mine projects, while the last two more detailed techniques could be used for existing minesites. Simple qualitative risk assessments have been used by regulatory agencies, either intentionally or unintentionally, in reviewing virtually all recent projects. The more sophisticated approaches have been applied relatively infrequently in mine assessments. Placer Dome Inc. is applying and developing several schemes for ARD analysis for all phases of mining development from exploration through closure. Risk assessments need to be applied more consistently to ensure that rational decisions are made in mine project development and that over conservative criteria are not used in project assessment.

CONTRIBUTION OF SPECIFIC MINERALS TO THE NEUTRALIZATION POTENTIAL IN STATIC TESTS
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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 551-566, ©2000

A reconnaissance study of the neutralization potential of 30 diverse minerals, 28 of which are silicates and aluminosilicates, has shown that most of these minerals contribute minimally to the neutralization potential (NP) in standard static tests. Feldspars in particular give low NP values and would not be expected to attenuate the acidity to any significant extent in acid rock drainage settings. The BET-determined surface areas of the minerals vary considerably, and the large surface areas of some of the

pulverized samples have clearly affected the NP values even though the standard static-test protocol was used for the preparation of the samples. The low NP values of most silicates and aluminosilicates are in general agreement with the laboratory-determined slow dissolution rates for these minerals. The results suggest that, in the prediction of whether rocks will be acid-producing, the most realistic measure is that of the carbonate content. In mine wastes from metalliferous ore deposits, the contribution to the NP by the non-carbonate gangue assemblage is unlikely to be more than a token amount until well after the establishment of an acid rock drainage situation.

THOUGHTS ON WAYS TO IMPROVE ACID DRAINAGE AND METAL LEACHING PREDICTION FOR METAL MINES
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Fifth International Conference on Acid Rock Drainage (ICARD), 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 675-682, ©2000

Modified after procedures for assessing acid-generating potential of coal spoils, most acid-base-accounting (ABA) analyses inadequately characterize highly varied metal deposits. Although mineralogy critically controls acid generation and metal leaching, acquisition of appropriate data and their interpretation are poorly developed. Metal loading rates are commonly determined by kinetic testing, which rarely duplicate actual field samples and conditions. Accurate predictions and reduced assessment costs can conceivably be achieved by use of geochemical analyses to define surrogate indicators; intelligent acquisition and use of mineralogical data; and, compilation of geo-environmental ore-deposit models to validate inference based on detailed geology.

A METHOD TO CALCULATE THE NEUTRALIZATION POTENTIAL OF MINING WASTES
Lawrence, R.W.; Michael Scheske
Environmental Geology, Vol 32 No 2, p 100-106, 15 Sep 1997

The determination of neutralization potential (NP) of mining wastes is an essential part of waste characterization for acid rock drainage (ARD) prediction. Interpretation of NP values requires consideration of the mineralogical composition of the waste. Different minerals can neutralize acid drainage at different rates and in different pH ranges. The test conditions of widely used laboratory procedures to determine NP do not distinguish between such differences and overestimation of NP can often result. A simple procedure is proposed in which the effective NP is calculated based on mineralogical composition and the relative reactivities of component minerals. Mineralogical composition is calculated from easily determined analytical values using a CIPW normative procedure.
Comparison of calculated NP values for 92 samples with experimentally determined values from tests designed to prevent the overestimation of NP indicates that the method is successful in predicting an effective NP value in most cases. The procedure is considered to be a cost-effective means of providing confident routine ARD prediction when used in combination with other tests and analyses.

ACID ROCK DRAINAGE PREDICTION FOR LOW-SULFIDE, LOW-NEUTRALIZATION POTENTIAL MINE WASTES
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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1,

p 567-580, ©2000

Prediction of acid rock drainage (ARD) for low-sulfide, low-neutralization potential (LSLNP) mine wastes is methodologically different from that for normal sulfidic mining wastes. In this paper, LSLNP wastes are conveniently defined as those with S2- <1% and ABA-NP2 <20 kg CaCO3 eq/t. The distinctiveness of ARD prediction for LSLNP materials originates from their frequently low oxidation rates and is mainly attributable to two reasons. First, the utilization efficiency of available carbonate neutralization potential (CNP2) rapidly deteriorates when the sulfide oxidation rate per unit mass of waste drops below a certain level. Second, silicate neutralization becomes increasingly important as oxidation rates diminish, and can no longer be ignored in LSLNP materials as it often is for normal sulfidic mine wastes. In this paper, the effects of oxidation rate, pore gas CO2 partial pressure, and flushing rate on ARD prediction for LSLNP materials are theoretically demonstrated. A new methodology for ARD prediction for LSLNP materials is presented. A case study validates some of the theoretical aspects discussed and illustrates the use of the proposed ARD prediction procedure.

COMPARISON OF PREDICTED ACIDIC DRAINAGE POTENTIAL TO FIELD WATER QUALITY AT A LOW SULFUR COAL MINE

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Fifth International Conference on Acid Rock Drainage (ICARD), 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 701-712, ©2000

A detailed assessment of acid rock drainage (ARD) potential was conducted at the Quintette Coal mine site in northeastern British Columbia. The site is unusual in that the coal seams contain low sulfur levels (typically less than 0.5%), and the non-coal wastes generally do not have the potential to generate acid on the basis of static acid-base accounting (ABA) tests. The presence of iron-stained seeps on the pit walls indicate localized sulfide oxidation, while the overall mine site drainage has remained of excellent quality with low levels of metals after 15 years of mining. Thus the site provides an excellent comparison to more problematic coal mine sites. Static ABA analyses of individual samples were compared to criteria for potentially acid generating materials developed for the U.S. Appalachian coal, as well as criteria developed in British Columbia for hard rock mines.

ASSESSING THE SUBAQUEOUS STABILITY OF OXIDIZED WASTE ROCK

MEND Secretariat CANMET, Ottawa, Ontario. MEND Report 2.36.3, Apr 1999

Waste rock is typically stored in a subaerial environment, a setting that may promote the oxidation of sulphide minerals and therefore be conducive to the initiation of acid rock drainage (ARD) and commensurate trace metal release. To mitigate this problem several strategies are currently being employed and tested by the mining industry including the subaqueous disposal of sulphide-rich waste rock. Subaqueous disposal has a number of features that make it attractive as a long-term storage option. However, the secondary mineral assemblages that accumulate during subaerial exposure could have a profound influence on the geochemical behaviour of the waste when submerged, such that deleterious effects on water quality may result. In order to assess adequately the environmental implications of placing oxidized waste rock underwater, techniques must be developed to allow proponents and government agencies to evaluate scientifically, and ultimately predict, the potential water quality impacts of this waste rock management strategy. The proposed sequential extraction method can be used as an effective tool to assess metal-phase associations in waste rock when more direct methods (e.g., SEM, XRD, etc.) become

too expensive and time consuming due to the fine grained/amorphous nature of many secondary minerals. Although the extraction alone cannot predict quantitative water quality impacts due to kinetic controls on mineral dissolution, when combined with kinetic or in-situ testing it is an effective tool to assess environmental risk associated with the subaqueous disposal of oxidized waste rock.

DETERMINATION OF NEUTRALIZATION POTENTIAL FOR ACID ROCK DRAINAGE PREDICTION

MEND Secretariat CANMET, Ottawa, Ontario. MEND Project 1.16.3, Jul 1996

A study has been carried out to evaluate static test methods for determining the neutralization potential, NP, of mining waste as part of prediction testing for acid rock drainage. In particular, results of the widely used Sobek method under standard and altered conditions have been assessed and compared with those obtained from the Modified procedure of Lawrence and with those based on the inorganic carbon content (Carbonate NP). The method of Lapakko has also been assessed for selected samples. Special attention has been given to the effect of mineralogical composition in interpreting NP results. A supplemental method to determine NP based on a calculated mineralogical composition and mineral reactivity has been proposed and results compared with the empirical methods of determination. 120 samples of waste rock or tailings from 12 mines were used in the study.

GUIDE FOR PREDICTING WATER CHEMISTRY FROM WASTE ROCK PILES

MEND Secretariat CANMET, Ottawa, Ontario. MEND Project 1.27.1a , Jul 1996

The Mine Environment Neutral Drainage (MEND) Program is developing tools for prediction of waste rock dump leachate quality. The first objective of this study was to evaluate a recently proposed empirical approach for predicting concentrations of metals in waste rock dump leachate primarily using pH (Morin and Hutt 1993). The method has previously been successfully applied at two mines. The second objective was to investigate refinements to the approach.

PREDICTION: PREDICTING ACID DRAINAGE

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Groundwork, No 1 Vol 2, Sep 1998 (Available online at http://www.ameef.com.au/groundwk.htm)

This paper explains the tests available for predicting the likelihood and magnitude of acid drainage. Acid drainage from mining operations has a long history dating back thousands of years to Phoenician times when the Iberian Pyritic Belt in Spain, from where the Rio Tinto (Red River) flows, was first exploited. Despite this long history, it wasn't until August 1977 that the first major piece of legislation was enacted which specifically targeted acid generating mine materials and required operators to identify these materials ahead of mining. This U.S. Act, The Surface Mining Control and Reclamation Act, was specific to the U.S. coal mining industry and required the burial of toxic material. Environmental concerns in the late 1960s and early 1970s focused on acid spoil and revegetation problems and it was agronomists who searched for ways to establish plants on these acid spoils. Acid drainage was considered a by-product of mining and was handled by treatment rather than control. Since the mid 1970s however, the focus has shifted to prevention technologies, with companies seeking to minimize bond commitments and the financial liability associated with on-going treatment.

ADVANCES IN ACID DRAINAGE PREDICTION USING THE NET ACID GENERATING (NAG)

TEST
Miller, S.; A. Robertson; T. Donahue
Environmental Geochemistry International Pty Ltd., Balmain, NSW (Australia)
Fourth International Conference on Acid Rock Drainage, 31 May-6 June 1997, Vancouver, Canada
CANMET, Natural Resources Canada, Ottawa, ON (Canada). Vol 2, p 533-549, 1997

A three-year research project to evaluate and develop the net acid generating (NAG) test for identification and characterization of acid-forming mine rock and wastes is described. Samples from 17 mine sites from eight mining companies were tested. The 119 samples include process residues and rejects, waste rock, and ore. Samples were subjected to the following test procedures: pH and electrical conductivity tests, acid neutralizing capacity, total sulphur, net acid producing potential (NAPP), static and kinetic NAG tests, mineralogical study, and column leaching test work. The kinetics of the NAG test for predicting the exposure period required for development of acid conditions (field lag) under natural weathering is described. The results show that NAG test is simple, inexpensive, and suitable for field use. It is a separate test of acid generating potential, however, and not an alternative to NAPP.

OBSERVATIONS AND LESSONS FROM THE INTERNATIONAL STATIC DATABASE (ISD) ON NEUTRALIZING CAPACITY
Morin, K.A.; N.M. Hutt
Minesite Drainage Assessment Group, Vancouver, BC
Fifth International Conference on Acid Rock Drainage (ICARD), 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 603-611, ©2000

Geochemical static tests are a basic component of geochemical assessments and predictions for acidic drainage, and include acid-base accounting and total-metal contents. A key database for such information is the International Static Database (ISD), which currently contains more than 45,000 static-test analyses from over 200 minesites. Such large databases are useful in identifying general trends and, just as important, the percentage of exceptions. General trends and significant exceptions can be seen in the ISD by comparing one parameter against another. This paper shows that bulk neutralization potential (bulk NP) obtained from acid titration is often a good indicator of neutralizing capacity above values of 10 t CaCO3/1000 t. Other types of calculated neutralizing capacity are then compared to bulk NP to determine if they, in fact, reliably represent actual neutralizing capacity and if they can substitute for the more time-consuming and expensive bulk NP.

LESSONS LEARNED FROM LONG-TERM AND LARGE-BATCH HUMIDITY CELLS
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Fifth International Conference on Acid Rock Drainage (ICARD), 21-24 May 2000, Denver, Colorado
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 661-671, ©2000

The Sobek humidity cell has been in use with minor modification for more than 30 years to determine bulk primary-mineral reaction rates. As a result, it has become a key tool for predicting the bulk rate of sulfide oxidation, the Carbonate Mole Ratio (CMR) of neutralization-potential (NP) consumption to sulfide oxidation, and the rates of metal leaching. Most humidity cells are operated for less than a year, with the resulting rates extrapolated into the future for years or decades. The validity of these extrapolations was tested by examining longer trends from cells that have operated for three to seven years,

as found in the International Kinetic Database (IKD). Additionally, large batches of cells for two minesites in the IKD (45 and 46 cells each) were examined to determine if regular, predictable trends were obtained across ranges of geochemistry at a minesite. The long-term cells show that the rates of sulfide oxidation and acid generation, based on sulfate production, have a 50% chance of stabilizing within one year, with the remainder fluctuating significantly throughout the test periods.

DISCRETE-ZONE MIXING OF NET-ACID-NEUTRALIZING AND NET-ACID-GENERATING ROCK: AVOIDING THE ARGUMENT OVER APPROPRIATE RATIOS

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Fifth International Conference on Acid Rock Drainage (ICARD), 21-24 May 2000, Denver, Colorado
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 2, p 797-803, ©2000

There is currently some pessimism over mixing of net-acid-neutralizing (NAN) and net-acid-generating (NAG) rock to obtain indefinite near-neutral seepage from mined-rock piles. This is due in large part to the lack of well-documented, successful cases of blending and layering, and to the knowledge of unsuccessful attempts. Past work often defined a potentially successful mix in terms of the ratio of NAN rock to NAG rock. For example, one case study indicated the bulk pile-wide ratio was approximately 3:1. Since this exceeded a common ratio used in acid-base accounting, no acidic drainage was predicted. However, acidic drainage appeared within two years. A large part of the ambiguity in mixing arises from attempts to predict success based on a ratio. This paper looks in detail at simple discrete-zone mixing. The paper is available online at http://www.mdag.com/publishing.htm

INTERNET CASE STUDY FOR NOVEMBER 1999: PREDICTION OF MINESITE-DRAINAGE CHEMISTRY USING THE "WHEEL" APPROACH

Morin, K.A.; N.M. Hutt

This Internet Case Study offers an overview on the common approach for predicting minesite-drainage chemistry. It pulls together and integrates most of the previous Case Studies at this website. The prediction of minesite-drainage chemistry is important to mining companies, regulatory agencies, and the interested public. For proposed minesites, prediction will reveal the watersheds and ground-water flow paths that will likely require controls upon mining. For operating minesites, prediction will indicate if current chemistry could worsen and thus require additional efforts and costs. For closed minesites, predictions of times until improvement can affect security costs and net-present-value estimates of closure costs. No one method or technique is capable of reliably predicting future drainage chemistry. Instead, a combination of tests, sometimes called the "Wheel" approach, is needed. The Wheel is an integrated approach requiring that most of the techniques be conducted. A bicycle wheel does not work unless most of the spokes are in place, and this holds true of the predictive Wheel. Due to site-specific limitations and method weaknesses, not all techniques under the Wheel are required or even possible at each minesite. For example, a proposed minesite does not yet have full-scale monitoring data, so this portion of the Wheel would be unavailable. Also, the weaknesses of some methods, like the NAG test, are not yet well understood, so that portion of the Wheel may not be implemented. Nevertheless, as many of the techniques as possible should be conducted and predictions from each compared. If any discrepancies appear, then further work must be done to resolve the discrepancies and to obtain consistent predictions.

Each technique in the Wheel is discussed separately. For additional information: http://www.mdag.com/cs11-99.htm

KINETIC TESTS AND RISK ASSESSMENT FOR ARD

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Fifth Annual British Columbia Metal Leaching and ARD Workshop, 9-10 December 1998, Vancouver, British Columbia, Canada

British Columbia Ministry of Energy and Mines, 1998

This paper examines the relationship between geochemical kinetic tests and the assessment of risk for ARD. A classic definition of risk depends on the likelihood that ARD will appear and the consequence if it does. The consequence of ARD is generally independent of kinetic tests, so the focus in this paper is placed on the relationship between kinetic tests and the prediction of ARD likelihood. Standard international practice involves the “Wheel” approach, in which several types of static and kinetic tests are conducted and compared. Therefore, kinetic tests alone should never be used for ARD predictions. This minimizes errors in ARD likelihood. The most common kinetic tests are laboratory-based columns and humidity cells and field-based test pads. Unlike columns and pads which often do not often provide any unique information under the Wheel, humidity cells typically provide primary-mineral rates without the complication of secondary-mineral precipitation. For ARD likelihood, they provide the relative rates of NP consumption and acid generation, which are critical for (1) estimating the duration of these reactions and (2) separating net-acid-generating from net-acid-neutralizing rock with a site-specific NPR (=NP/AP) value under acid-base accounting. The paper is available online at http://www.mdag.com/publishing.htm

INTERNET CASE STUDY FOR FEBRUARY 1998: CONTROL OF MINESITE-DRAINAGE CHEMISTRY: WHY AND HOW MUCH DOES IT COST?

Morin, K.A.; Nora M. Hutt

This Internet case study is adapted from Chapter 6 of Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies, ©1998

Where the chemistry of minesite drainage is unacceptable for release to the environment, there must be some type of control prior to release in order to minimize damage to the environment. There are two basic approaches to drainage-chemistry control: reactive ("we'll handle it when it happens") and proactive ("a stitch in time saves nine"). While proactive controls sounds best, it can actually be more expensive, riskier to the environment, and requires detailed predictive work to control the timing, extent, and severity of the potential problem. If the predictive work is wrong, proactive work may turn out to be fruitless. For additional information: http://www.mdag.com/cs2-98.htm

INTERNET CASE STUDY FOR MARCH 1998: MINESITES ARE MADE OF DISTINCT COMPONENTS

Morin, K.A.; Nora M. Hutt

This Internet case study was developed from information in Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies, ©1998

When considering surface and ground waters draining from a minesite, some people believe the entire site contributes to the observed concentrations in the drainage. This is incorrect. In reality, a minesite consists of one or more components, and each component can have a unique effect on drainage chemistry.

For instance, 90% of elevated off-site concentrations may originate from only one component, while all other components contribute the remaining 10%. In this example, it can be economically foolish to spend equal amounts of money on each component for drainage-chemistry control (see our Internet case study for February 1998). It may be wiser and environmentally more prudent to focus most of the budget on the most problematic component. Therefore, there are two basic steps to properly and prudently assess, predict, and control drainage chemistry at a particular minesite: 1) all components must be identified and studied, and 2) the interactions among the components must be defined. This Internet Case Study discusses some of the components that can exist on a minesite. Site photographs will help to illustrate the points. For additional information: http://www.mdag.com/cs3-98.htm

A COMPARISON OF AMD PREDICTIONS WITH HISTORICAL RECORDS
Morin, K.A.; N.M. Hutt
Proceedings of the Workshop on Acid Mine Drainage, 15-18 July 1997, Darwin, Northern Territory, Australia
Australian Centre for Minesite Rehabilitation Research, p 33-44, 1997

INTERNET CASE STUDY FOR NOVEMBER 1997: NEUTRALIZATION POTENTIAL—WHAT IS IT AND WHY IS IT IMPORTANT FOR DRAINAGE CHEMISTRY?
Morin, K.A.; N.M. Hutt
This case study is adapted from Chapter 5 of Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies, ©1997

One of the most misunderstood concepts in the prediction of drainage chemistry is "neutralization potential" (NP). For acidic-drainage predictions, NP basically represents the amount of acidity that can be neutralized by a sample of rock, tailings, or soil. For alkaline-drainage predictions, NP represents the amount of base that can be released into drainage waters. NP has historically been defined as the result of a laboratory analysis. However, as the number of methods for NP has increased, an interesting problem has arisen: for a particular sample, each method gives a different value of NP. Long ignored has been the question of which is correct. The answer is not so obvious because, to come full circle, NP is simply the result of a laboratory analysis. So all are right! See case study at http://www.mdag.com/cs11-97.htm

AN EMPIRICAL TECHNIQUE FOR PREDICTING THE CHEMISTRY OF WATER SEEPING FROM MINE-ROCK PILES
Morin, K.A.; N.M. Hutt
Proceedings of the International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage, 24-30 Apr 1994, Pittsburgh, PA
Report No: BUMINES-SP-06A-94. NTIS: PB96-113519NEG. Vol 1, p 285-293, 1994

PREDICTION OF MINEWATER CHEMISTRY FROM AVAILABLE MONITORING DATA, NORANDA MINERALS' BELL MINE, BRITISH COLUMBIA
Morin, K.A.; N.M. Hutt; R. McArthur
Third International Conference on the Abatement of Acidic Drainage, 24-30 Apr 1994, Pittsburgh, Pennsylvania
Report No: BUMINES-SP-06A-94. NTIS: PB96-113519NEG. Vol 2, p 422, 1994

THE USE OF ROUTINE MONITORING DATA FOR ASSESSMENT AND PREDICTION OF WATER CHEMISTRY
Morin, K.A.; N.M. Hutt
Seventeenth Annual Mine Reclamation Symposium, 4-7 May 1993, Port Hardy, British Columbia
Mining Association of British Columbia. p 191-201, 1993

AN INTEGRATED APPROACH TO ASSESS ACID GENERATION AND METAL RELEASE FROM SULFIDE TAILINGS USING OXYGEN CONSUMPTION MEASUREMENTS, POREWATER CHEMISTRY AND GEOCHEMICAL MODELING
Nicholson, R.V. (BEAK International, Inc., Brampton, ON, Canada, and Univ. of Waterloo, Waterloo, ON, Canada); M.J. Rinker; P.A. Tibble; G. Williams; M. Wiseman (Falconbridge Ltd., Timmons, ON)
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Tailings, from an active copper-zinc operation, containing about 10% sulfur were investigated to assess the onset of acid production and potential lime requirements for treatment of drainage. Oxygen consumption rates were measured over two years to verify spatial and seasonal variations in sulfide oxidation rates. Shallow cores were collected to assess the quality of tailings porewater and to characterize solids that had been subjected to oxidation and depletion of neutralization potential (NP) for several years. Oxygen consumption data were used to quantify rates of NP depletion and onset of acid drainage from the near-surface tailings. Based on measured oxygen consumption rates and identification of NP remaining in the tailings, future lime use in the treatment plant was expected to rise significantly without mitigation. Geochemical modeling calculations were calibrated with observed oxygen consumption rates and the model results agreed well with actual lime use in the waste water treatment plant during operations.

PREDICTION OF ACIDIC DRAINAGE AND ACCOMPANYING METAL RELEASES FROM UNSEGREGATED PYRITIC URANIUM MILL TAILINGS BASED ON EFFLUENT CHEMISTRY AND POST LEACHING SAMPLE MINERALOGY
Paktunc, A.D.; N.K. Dave, CANMET, Ottawa, ON
Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 2, p 891-900, ©2000

Unsegregated pyritic uranium mill tailings from Elliot Lake, ON, with and without limestone amendment, were subjected to column leaching experiments for the purposes of predicting the onset of acidic drainage and the magnitude of metal and radionuclide release under various treatment and control strategies. The unamended tailings produced acidic drainage after approximately one and a half years. The tailings mixed with various grain-sized limestone did not produce acidic drainage during the study period. The tailings consist essentially of quartz, K-feldspar, muscovite and pyrite. The unsegregated tailings amended with very fine limestone displayed the least amounts of pyrite loss whereas those without limestone amendment had the greatest pyrite losses. Predicted onset of acid generation varied from 16 to 75 years for the top sections and in most cases greater than 100 years for bottom sections of the unsegregated tailings with limestone amendments. Unsegregated tailings mixed with fine- and very fine-grained limestone proved to be the most effective in controlling or delaying the onset of acidic drainage under unsaturated conditions.

MINERALOGICAL CONSTRAINTS ON THE DETERMINATION OF NEUTRALIZATION POTENTIAL AND PREDICTION OF ACID MINE DRAINAGE
Paktunc, A.D.
Environmental Geology, Vol 39 No 2, p 103-112, 16 Dec 1999

Acid-base accounting tests, commonly used as a screening tool in acid mine drainage (AMD) predictions, have limitations in (1) measuring with confidence the amount of neutralizers present in samples and (2) affording an interpretation of what the test results mean in terms of predicting the occurrence of acid mine drainage. Aside from the analytical difficulties inherent to the conventional methods, a potential source of error in neutralization potential (NP) measurements is the contribution from the dissolution of non-carbonate minerals. Non-carbonate alkalinity measured during static tests may or may not be available to neutralize acidity produced in the field. In order to assess the value-added of extending the NP with the knowledge of mineralogical composition and evaluate potential sources of errors in NP measurements, a suite of samples were examined and characterized in terms of their mineralogical and chemical compositions. The results indicate that although the acid-base accounting tests work well for simple compositions, the tests may result in overestimation or underestimation of NP values for field samples. Mineralogical constraint diagrams relating NP determinations to Ca, Mg and CO2 concentrations were developed with the purpose to serve as supplementary guides to conventional static tests in identifying possible NP contributions from non-carbonate minerals and checking the quality of the chemical testing results. Mineralogical NP makes it possible to interpret the meaning of NP results and to assess the behaviour of samples over time by predicting the onset of AMD and calculating NP values for individual size fractions.

COAL MINE DRAINAGE PREDICTION AND POLLUTION PREVENTION IN PENNSYLVANIA
Pennsylvania Dept. of Environmental Protection
400 pp, Oct 1998

This manual contains 18 chapters by more than 20 different authors. It is a technical reference document that discusses recent research and advanced scientific thinking about predicting mine drainage quality and preventing mine drainage pollution. The manual is available at http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/main.htm

PREDICTION OF ACID MINE DRAINAGE POTENTIAL OF GEOTHERMAL SOLID WASTES
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Twenty-Second Annual Workshop Geothermal Reservoir Engineering, 27-29 January 1997

Geothermal solid wastes such as scale and sludge from the Philippines and Mexico containing Cu, Zn, and Pb at levels above earth's crustal abundance were studied for their acidification potential if disposed in a landfill. This will assess whether the materials can be considered hazardous or not. A batch reactor technique using the iron and sulfur oxidizing bacteria Thiobacillus ferrooxidans had been developed for geothermal wastes to predict their acid mine drainage and bioleaching potential. The effects of agitation, temperature, and sterilization on metal leaching were investigated. It was observed that almost 100% of Cu and Zn in the Mexican scale and less than 2% in the Philippine scale and sludge were released while Pb, the regulated element, was not found in the leachate since it precipitated as PbSO4. Implications on possible waste treatment and disposal programs will be discussed.

EVALUATION OF HUMIDITY CELL PARAMETERS: THEIR EFFECT ON PRECISION AND REPEATABILITY

Pool, D.L.; R.M. Balderrama, Bureau of Mines, Reno, NV. Reno Research Center

Proceedings of the International Land Reclamation and Mine Drainage Conference and Third International Conference on the Abatement of Acidic Drainage, 24-30 Apr 1994, Pittsburgh, PA
Report No: BUMINES-SP-06B-94. NTIS: PB96-113493. Vol 2, p 326-333, 1994

The prediction of acid rock drainage (ARD) from mineral processing tailings is an inexact procedure, and variations in results are common. The U.S. Bureau of Mines has evaluated the major parameters associated with humidity cell tests to determine their effect on the test's precision and repeatability. A set of 44-week tests on 50-year-old tailings was performed with temperature control and changes in effluent volume and airflow. The temperature was maintained at 30 [plus or minus] 1 C. The airflow across the sample surface during the dry and wet air portions of the cycle was set at either 250 or 500 ml/min. The leach solution volume was varied to recover an effluent equivalent to up to 50% of the sample mass. The responses monitored were moisture removed during air addition, effluent volume, and acid in effluent (the amount of base required to titrate to pH 6), and total soluble sulfur. Changes in airflow and effluent volume affected the amounts of sulfate and acid reporting to effluent. Increased airflow resulted in more moisture removal and increased acid generation. As the effluent volume was varied, a maximum for acid generation was observed at 100 ml/325 g of sample. The data indicate that consistency in airflow and ratio of effluent volume to sample mass may improve the precision of the humidity cell test data. In addition, titration of the effluent provided a better measure of the acid content of the effluent than did pH monitoring. Precise and repeatable data should make the comparison of humidity cell data and ARD prediction between samples and testing facilities more reliable.

GUIDELINES FOR THE PREDICTION OF ACID ROCK DRAINAGE AND METAL LEACHING FOR MINES IN BRITISH COLUMBIA: PART II. RECOMMENDED PROCEDURES FOR STATIC AND KINETIC TESTING

Price, W.A.; K.A. Morin; N.M. Hutt

Fourth International Conference on Acid Rock Drainage (ICARD), May 31-June 6 1997, Vancouver, BC, Canada
MEND Secretariat CANMET, Ottawa, Ontario. Vol 1, p 15-30, 1997

USE OF THE NET ACID GENERATION PH TEST FOR ASSESSING RISK OF ACID GENERATION

Schafer, W.M., Shepherd Miller, Bozeman, MT

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 613-619, ©2000

The net acid generation (NAG) pH method is an important analytical tool that supplements static and kinetic tests for assessment of the acid generation risk of rock samples. This method is useful because it is simple, rapid and cost-effective; it combines features of the static and kinetic tests; and it can be conducted at mine assay labs. The NAG pH test is particularly effective for operational testing programs used to classify, selectively handle, and route potentially acid-generating waste rock. The NAG pH procedure is based on a 24-hour oxidation of a pulverized rock sample with hydrogen peroxide and subsequent measurement of the sample's pH. If the NAG pH is below a critical value, determined empirically, then the sample has the potential to generate acid in the field. The critical NAG pH value is

typically within the range of 3 to 4.5, but the exact relationship between NAG pH and potential acid generation should be determined individually for each mine site. Calibration and use of the NAG test for predicting ARD risk at several mines are described in this paper.

LIMITATIONS OF ACID-BASE ACCOUNTING FOR PREDICTING ACID ROCK DRAINAGE
Scharer, J.M.; L. Bolduc; C.M. Pettit; B.E. Halbert, SENES Consultants, Ltd., Richmond Hill, ON
Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 591-602, ©2000

The ratio of neutralization potential (NP) to acid production (AP) ratio is often employed for predicting acidic discharges from waste rock dumps. The available NP was evaluated in laboratory studies of limestone dissolution in simulated acidic mine water. The available neutralization potential strongly depended on the particle size. Using limestone particles of 1/4" (6.4 mm) or greater, less than 20% of the total neutralization potential was exhausted at the onset of acid conditions. Apparently, the dissolution of limestone became mass transfer limited. Under mass transfer limitations, the rate of pyrite oxidation may exceed the rate of neutralization by buffering minerals. The implications concerning the controls on limestone dissolution were examined using a geochemical predictive model for sulfide mineral oxidation in waste rock. The results have shown that in case of heterogeneous waste rock piles the NP/AP ratio is a reliable indicator for short-term predictions only. Kinetic data on the depletion rate of the neutralizing minerals and geochemical modeling suggest that waste rock environments with NP/AP ratios as high as 5.0 may turn acidic in the long term.

CASE STUDY 1: USING GEOLOGICAL DATA TO PREDICT ACID DRAINAGE
Scott, Peter (Woodward-Clyde, Brisbane); Graeme Eastwood (Newcrest Mining Ltd.)
Groundwork, No 1 Vol 2, Sep 1998 (Available online at http://www.ameef.com.au/groundwk.htm)

The authors discuss how geological data can be used to define the potential for acid drainage before a mine begins operations. Effective control and management of acid drainage requires the integration of acid drainage testing with an early insight into the spatial distribution and potential volumes of the acid producing material that may result from mining. This can be facilitated by a comprehensive drillhole database and effective interrogation strategies. At its Cadia gold-copper deposit in NSW, Newcrest Mining's geological staff and Woodward-Clyde (Brisbane) have adopted a system which integrates acid drainage testing of waste rock, geological database interrogation and mine waste block modeling to allow the company to predict, before mining, the acid generating potential of the waste rock which will be extracted as part of the mine operation.

ACID MINE DRAINAGE CONTROL AND TREATMENT
Skousen, Jeffrey G.; P.F. Ziemkiewicz
West Virginia Univ., National Mine Land Reclamation Center, Morgantown, WV. 255 pp, 1995

ACID MINE DRAINAGE PREDICTION
U.S. EPA, Office of Solid Waste
EPA 530-R-94-036, NTIS: PB94-201829. 49 pp, 1994